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Towards the assimilation of IASI Level 1 radiances for ozone and aerosols in a chemical transport model

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1 Abstract

Level 2 (L2) retrievals from the Infrared Atmospheric Sounding Interferometer (IASI) have been used, for several years, to correct ozone analysis provided by chemical transport models (CTMs). This is achieved by means of data assimilation algorithms. However, the quality of the analysis might be influenced by the prior information used for the O₃ retrievals. Another limitation is that desert dust aerosols have a significant influence in the region of the IASI spectrum used to retrieve ozone.

In this work, we evaluate the impact of assimilation of IASI Level 1 radiances including aerosols within the radiative transfer model on ozone analysis. We also evaluate the impact of including desert dusts in the control vector on their analysis.

We have computed hourly 3D-Var analyses assimilating L1 radiances from IASI in the chemical transport model MOCAGE. We have used a subset of 280 channels covering the spectral range between 980 and 1100 cm⁻¹. The impact of including aerosols in radiative transfer on ozone is presented. We also show the impact of taking into account desert dust in the control vector on their profiles.

2 Context and objectives

2.1 Why do we monitor ozone and aerosols ?

- **Ozone:**
 - Tropospheric ozone behaves as a **pollutant** with negative effects on vegetation and human health.
 - Tropospheric ozone contributes to **global warming** with a net positive effect.
 - The stratospheric ozone is a vital component of life on the Earth since it protects the **biosphere** from harmful ultraviolet.
 - Ozone is used recently to improve temperature in **NWP**.
- **Desert dusts:**
 - Desert dust outbreaks contribute directly to **air pollution** by increasing particulate matter concentrations.
 - Dust deposition impacts solar **photovoltaic** panels in desert environment.
 - Desert dusts interact with **climate**.

2.2 Assimilation: context and assumptions

- Level 1 have been introduced recently in the assimilation of ozone (Emili et al., 2019).
- L1 radiances assimilation have been improved using a realistic observation error covariance matrix (El Aabaribaoune et al., 2021).
- **The ozone band might be sensitive to desert dust.**
- **Assumption: The desert dusts effect is neglected so far.**

2.3 Objectives

- **Is the effect of desert dust negligible ?**
- **If not ? What will be the contribution of including aerosols in the radiative transfer on the analyses ?**

3 Methodology

3.1 Model: MOCAGE

- Developed at CNRM (Météo France). (Josse et al., 2004)
- Modelled processes: Sources, Sinks, Transport and Chemistry.
- Multiscale: regional and global.

3.2 Observations: IASI

- **IASI : Infrared Atmospheric sounding Interferometer (Metop-A)**
- Measures between 3 and 15 μm (645 and 2760 cm⁻¹). Spectral resolution 0.5 cm⁻¹.
- Spectral range used: between 980 and 1100 cm⁻¹ (ozone and surface skin temperature).

3.3 Assimilation method : 3D-Var

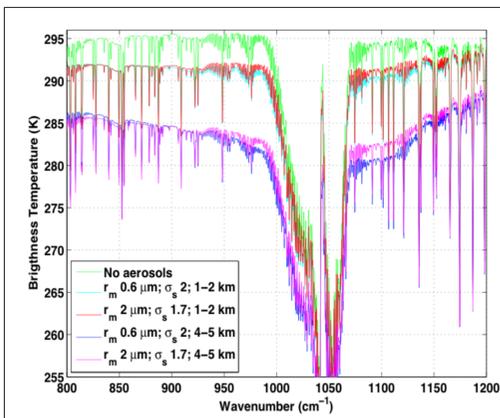
$$\mathcal{J}(\mathbf{x}) = \frac{1}{2}(\mathbf{x}_b - \mathbf{x})^T \mathbf{B}^{-1}(\mathbf{x}_b - \mathbf{x}) + \frac{1}{2}(\mathbf{y} - \mathcal{H}(\mathbf{x}))^T \mathbf{R}^{-1}(\mathbf{y} - \mathcal{H}(\mathbf{x}))$$

- **x_b** : Background . **y**: Observations. **H**: Observation operator.
- **B** : Background error covariances matrix.
- **R** : Observation error covariances matrix.

3.4 Radiative transfer model

- RTTOV (Radiative Transfer for TOVS) (R. Saunders and Brunel, 1999)
- Simulates radiances in the infrared and microwave spectrum.
- Takes as inputs an atmospheric profile of temperature, water vapor and, optionally, trace gases, aerosols and hydrometeors, together with surface parameters and a viewing geometry.

4 Sensitivity to the desert dusts



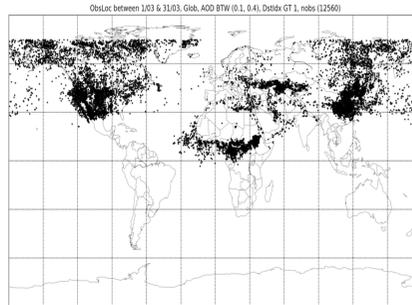
The radiance that would be observed by the IASI for two distributions associated with an aerosol layer at two different altitudes. The corresponding direct modelling in the absence of aerosols is also shown (green). Vandebussche et al., 2013.

5 Including aerosols in radiative transfer:

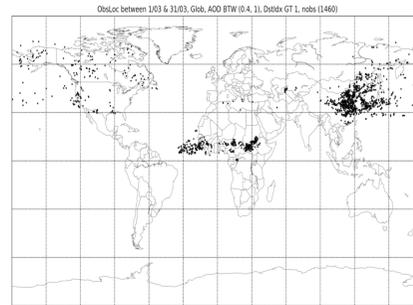
Period of the study: **March 2010**

5.1 Selection of the observations criteria :

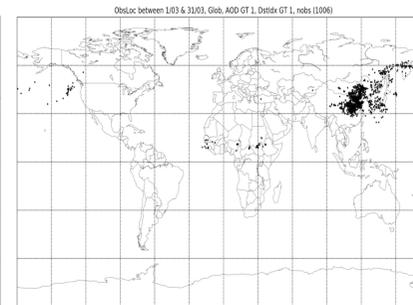
- **Model AOD:** The AOD of the model is interpolated to the observation location and three cases are considered: 0.1 < AOD < 0.4, 0.4 < AOD < 1 and AOD > 1.
- **Obs. Dust Index:** based on the V-shaped signature computed as $\text{Indx} = (\text{BT}_{829 \text{ cm}^{-1}} - \text{BT}_{972.5 \text{ cm}^{-1}}) + (\text{BT}_{1202.5 \text{ cm}^{-1}} - \text{BT}_{1096 \text{ cm}^{-1}})$. The observation with $\text{Indx} > 1$ are considered.



The observations used have an AOD between 0.1 and 0.4.



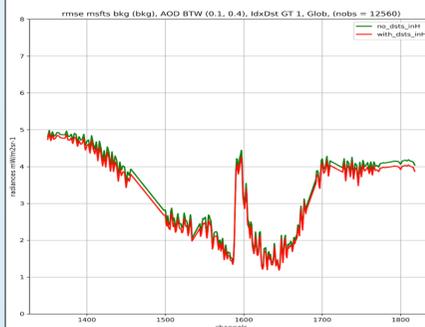
The observations used have an AOD between 0.4 and 1.



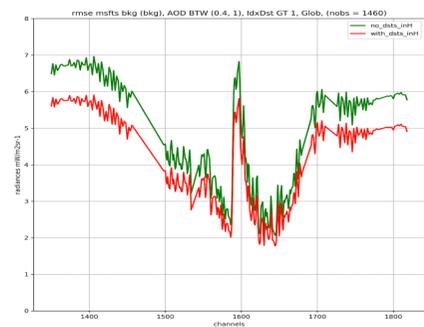
The observations used have an AOD greater than 1.

5.2 Impact on the misfits

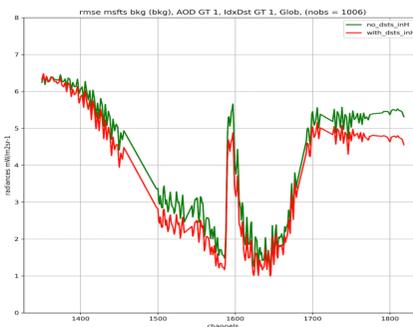
RMSE of the quantity Hxb-Y (the equivalent of the analysis minus the observation) with and without (red and green respectively) including desert dust in the radiative transfer but not in the control variable along the period of the study (march 2010).



The observations used have an AOD between 0.1 and 0.4.



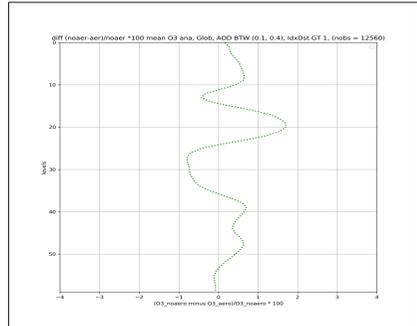
The observations used have an AOD between 0.4 and 1.



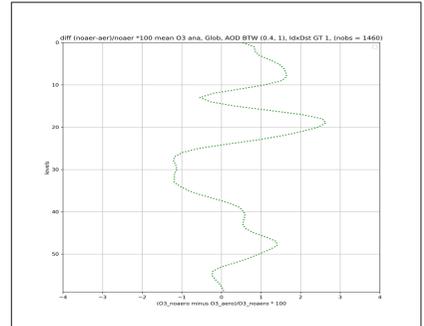
The observations used have an AOD greater than 1.

5.3 Impact on ozone analysis: vertical profile

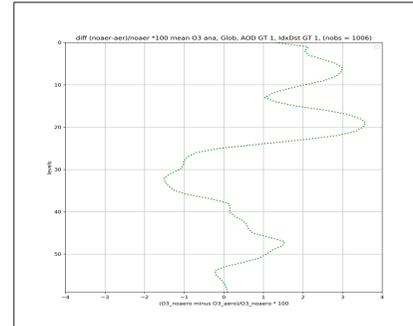
The difference between the ozone profile analysis with and without including aerosols in radiative transfer but not in the control variable along the period of the study (march 2010) as percentage of ozone profile analysis concentration without aerosols ((without aerosols minus with aerosols)/without aerosols).



The observations used have an AOD between 0.1 and 0.4.



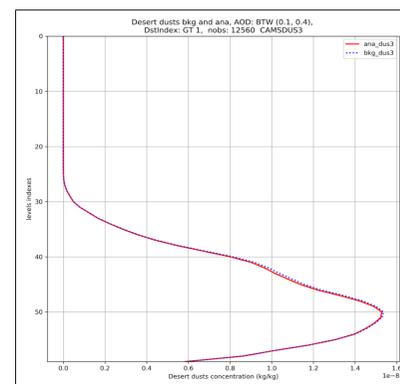
The observations used have an AOD between 0.4 and 1.



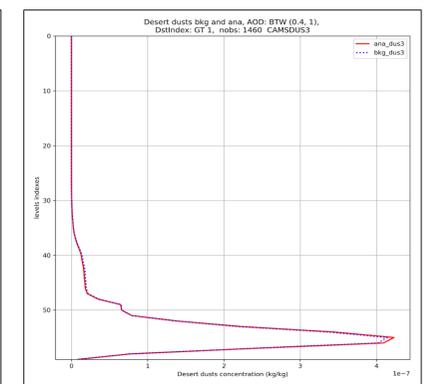
The observations used have an AOD greater than 1.

6 Including aerosols in the control vector: Impact on desert dusts vertical profile

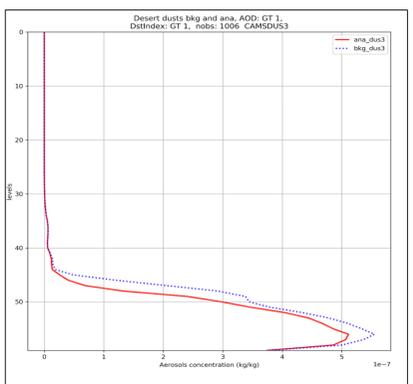
Desert dust profiles (analysis and background) from an assimilation experiment where desert dust are included in the control vector for the period of the study (march 2010). Here, we show dusts with size between 0.9 and 20 μm (CAMSDUS3).



The observations used have an AOD between 0.1 and 0.4.



The observations used have an AOD between 0.4 and 1.



The observations used have an AOD greater than 1.

7

Conclusions

- Desert dusts have an impact on the ozone band. This depending on the altitude and size of aerosols.
- Including desert dusts in the radiative transfer impacts ozone and the skin surface temperature analyses.
- Including desert dust in the control vector impacts the analysis comparing to the background.
 - Including aerosols in the control variable might improves ozone analysis, skin surface temperature at the same time of controlling aerosols.
 - Validate to independent data MLS, Ozonesondes, and MODIS.
 - Review the background error covariance matrix.

8

References

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Acknowledgements

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